Chiao Da Management Review
Vol. 35 No.2, 2015
pp. 1-29

運用整合性架構解決創新策略矛盾之研究

Resolving Partial-Viewpoint Paradoxes of Innovation Strategies: Toward an Integrative Framework

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摘要：本文系統化分析 1996 至 2012 年間社會科學引用指標 (SSCI) 及谷歌學術 (Google Scholar) 資料庫文獻，從知識管理觀點提出一個創新與效率、環境確定與不確定及時間軸的三維架構，整合創新的創造、選擇與擴散相關文獻，從三維空間中看到解決創新策略矛盾的觀點。本研究貢獻包含：(1) 解決因為不同研究者聚焦在不同特定二維平面所造成的矛盾，例如產業創新理論中供給面與需求面策略的矛盾，供給面策略主張產品發展早期追求產品創新效能而晚期追求成本效率 (Abernathy and Utterback, 1978)；需求面策略則是主張產品發展早期追求降低成本至顧客願意支付的價格，而晚期追求強化效能以穩定提升價格 (Adner and Levinthal, 2001)；(2) 提出實務中常用的創新產品性 (能) 價 (格) 比作為競爭策略指標並提供理論上合理的解釋；(3) 提供學習創新與技術管理的架構，促進知識發展，此動態三維整合架構可提供後續研究用來解決目前創新研究的相關矛盾。

關鍵詞：創新；選擇；擴散；效率；效能價格比

Abstract: This study follows a systematic literature review procedure of Social Sciences Citation Index (SSCI) and Google Scholar databases during 1996-2012. A three-dimensional framework is generated from a knowledge management perspective that integrates relevant studies of innovation creation, selection, and diffusion. The first dimension is innovation and efficiency; the second dimension

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is uncertain and certain environment; the third dimension is time. This study reviews the previous research concerning knowledge creating/diffusing mechanisms for innovation, autonomous strategic process, induced strategic process in the innovation strategy, the pattern of industrial innovation, and the S-curve in the diffusion of innovations. A method for resolving the current paradox resulting from researchers' viewpoints of supply-side (e.g., Abernathy and Utterback, 1978) and demand-side strategies (e.g., Adner and Levinthal, 2001) in industrial innovation is offered. Namely, supply-side strategists pursue an innovative product's performance in the early stage of product innovation process and cost efficiency in the late stage of the process. Contrarily, demand-side strategists advocate reducing product cost to ensure that customers are willing to pay for the product during the early stage of product innovation process; in the late stage of the process, strategists enhance product's performance to ensure the product's price stability. In addition, this study legitimates a functional product performance/cost ratio for competitive strategies in practice. Furthermore, this study encourages future studies to resolve innovation paradoxes from a dynamic three-dimensional perspective.

Keywords: Innovation; Selection; Diffusion; Efficiency; Performance/cost

1. Introduction

While single factor innovation studies have continued for fifteen years (e.g., Tidd, 2001; Corso *et al*., 2001; Johnson, Neave and Pazderka, 2002; Pittaway *et al*., 2004; Adams, Bessant and Phelps, 2006; Nicolini *et al*., 2008; Zheng, 2010) Drazin and Schoonhoven (1996) and have identified innovation as a mature body of research needing an integrative framework to encourage theory development in innovation. More recently Tidd (2001), Tao, Probert and Phaal (2010), and Berkhout, Hartmann and Trott (2010) have also called for an integrative framework to resolve paradoxes, provide managers clear and consistent guidelines for innovation management. Crossan and Apaydin (2010) described innovation as a interaction among leadership, process and outcome; Berkhout, Hartmann and Trott (2010) as a dynamic process; Daneels (2002) as a derivative of firm competencies taken jointly or severally. However, previous studies shown in Table 1 do not resolve the supply/demand paradox in industrial innovation.

Nonaka and his colleagues (1995; 1998) proposed a concept “Ba” (i.e., place for innovation) and built a theoretical foundation for knowledge creation (Nonaka and Konno, 1998), which enables companies to create the dynamics of innovation. Thus, this study attempts to build a three-dimensional framework for resolving this paradox by extending the work of Nonaka and his colleagues (1995; 1998). We re-conceptualize innovation as a dynamically three-dimensional process for resolving the paradox of supply-side and demand-side strategies in industrial innovation. Previous studies note that knowledge management plays an important role in the innovation process (Crossan and Apaydin, 2010; Nonaka and Takeuchi, 1995; Nonaka and Konno, 1998; Corso *et al.*, 2001; Johnson, Neave and Pazderka, 2002; Adams, Bessant and Phelps, 2006; Nicolini *et al.*, 2008; Cowan and Jonard, 2009; Huggins, 2010). In this study we investigate knowledge management from an individual, organization and industry level. Here, knowledge management includes identification, acquisition, creation, sharing, transfer, utilization, storing and accumulation of ideas, information or knowledge which generates innovation; industry includes market, economy, and society in this study.

2. Methodology

To examine multiple streams of innovation research for TIM knowledge development, we adopted a systematic review procedure comprised of three stages: planning, execution, and reporting (Transfield *et al.*, 2003; Crossan and Apaydin, 2010). During the planning stage, our objective was to resolve paradoxes resulting from a two-dimension’s partial perspective of the innovation process. We used the ISI Web of Science’s Social Sciences Citation Index (SSCI) and Google Scholar (GS) databases from 1996-2012: SSCI is a database collecting academic papers; GS also includes books. During the execution stage, we first used basic keywords: “innovation process” and “knowledge” as a selection criterion for the topic (title, keywords, or abstract), resulting in an initial sample of 3,821 papers and books (referred to as papers, hereafter). Since our objective was to resolve paradoxes in an innovation process from a broader perspective, we reviewed the topic by examining full articles when unsure to confirm that their focus was central to the objective of this paper. We then identified three major innovation process groups: 586 papers covered "creation", 138 papers dealt with "selection" while 329 papers focused on "diffusion". These three groups comprise the fundamental steps in an innovation process.

We further select papers from the top 10 innovation journals (Research Policy, Strategic Management Journal, Journal of Product Innovation Management, Management Science, Academy of Management Journal, Organization Science, Regional Studies, Administrative Science Quarterly, Academy of Management Review, and The Rand Journal of Economics), two innovation journals (Technovation and R&D Management), and two management review journals (Journal of Management Studies and International Journal of Management Reviews). Once the papers are selected for a review, the data analysis may proceed in different ways depending on the objectives of the review (Crossan and Apaydin, 2010). We thus analyze the above studies and categorized them by approach (contextual/dynamics) and by level (individual/ organization/industry). The former involves two major approaches in innovation studies (Drazin and Schoohoven, 1996); the latter reveals gaps between different analytic levels. Additionally, other studies show mechanisms bridging the gaps. Analysis of studies by different approaches, units of analysis, and mechanisms facilitated identification of key studies in the innovation process. We report these critical papers in Table 1.

3. Knowledge and Innovation Process

3.1 Examining Nonaka's Knowledge Creation

Knowledge is a crucial enabler for innovation (Corso *et al.*, 2001; Cowan and Jonard, 2009). Knowledge creation and diffusing activities both feed into and derive from the organization's core capabilities i.e., its knowledge assets

Table 1
Gaps between Innovation Research Levels and Mechanisms for Bridging the Gaps

Approach / Level	*Context approach (Cross-sectional designs)*	*Dynamics approach (Longitudinal, event-histories)*	*Mechanisms for bridging gaps between individual, organization and industry levels*
Individual/ Team/ Group	Make sense of knowledge (Orlikowski and Gash, 1994) Tacit knowledge (Leonard and Sensiper, 1998)	Tacit/Explicit knowledge (Nonaka and Takeuchi, 1995; Nonaka and Konno, 1998) Individual/Social knowledge (von Krough, 1998)	1. Socialization/externalization/combination/internalization 2. Dialogue/linking explicit knowledge/learning by doing/field building 3. Sharing tacit knowledge/creating a concept/justifying the concept/building an archetype/obtaining cross-leveling knowledge over time (Nonaka and Takeuchi, 1995)
Organization	Organization's ability to innovate (Cohen and Levinthal, 1990; Nonaka and Takeuchi, 1995; Leonard-Barton, 1995; Eisenhardt and Tabrizi, 1995; Drazin and Schoohoven, 1996; Edmondson *et al.*, 2001; Haunschild and Miner, 1997; McGrath, 2001; Power *et al.*, 1996; Sorensen and Stuart, 2000; Tidd, 2001; Corso *et al.*, 2001; Lewis *et al.*, 2002; Johnson, Neave and Pazderka, 2002; Pittaway *et al.*, 2004; Adams, Bessant and Phelps, 2006; Crossan and Apaydin, 2010; Marion and Meyer, 2011)	Organization's ability to innovate (Abernathy and Utterback, 1978; Nonaka and Takeuchi, 1995; Leonard-Barton, 1995; Drazin and Schoohoven, 1996; Denison *et al.*, 1996; Hargadon and Sutton, 1997; Tushman and Oreilly, 1996; Nonaka and Konno, 1998; Brown and Duguid, 1998; Adner and Levinthal, 2001; Danneels, 2002; Tao, Probert and Phaal, 2010; Berkhout, Hartmann and Trott, 2010; Gassmann *et al.*, 2012)	1. Problem solving/implementing and integrating knowledge/experimenting knowledge/importing knowledge (Leonard-Barton, 1995) 2. Autonomous strategic process/induced strategic process (Burgelman *et al.*, 2004)
Industry/ Market/ Society	Industry's ability to innovate (Drazin and Schoohoven, 1996; Nicolini *et al.*, 2008)	Diffusion of innovations (Rogers, 2003; Drazin and Schoohoven, 1996; Berkhout, Hartmann and Trott, 2010)	1. Patterns of industrial innovation (Abernathy and Utterback, 1978) 2. Diffusion of innovations (Rogers, 2003) 3. Variation/Selection/Retention (Tushman and Oreilly, 1996) 4. Demand heterogeneity and technology evolution (Adner and Levinthal, 2001)

(Leonard-Barton, 1995; Schilling and Kluge, 2009; Li and Tsai, 2009). Knowledge management is a dynamic management of the process of creating knowledge out of knowledge (Nonaka and Konno, 1998; Corso *et al*., 2001; Nicolini *et al*., 2008; Meier, 2011; Lin and Wu, 2011). Thus, innovation is an outcome of sound knowledge management (Corso *et al*., 2001; Johnson, Neave and Pazderka, 2002; Adams, Bessant and Phelps, 2006; Nicolini *et al*., 2008) and provides a foundation to build a framework for integrating innovation research.

Organizational knowledge is shared through a spiral process referred to as SECI modes: (1) socialization (tacit knowledge amplification); (2) externalization (transfer of tacit knowledge to explicit knowledge); (3) combination (explicit knowledge amplification); and (4) internalization (transfer of explicit knowledge to tacit knowledge). The SECI modes contain both tacit and explicit knowledge that is transferred via four activities in the environment ("Ba" in Nonaka and Takeuchi's term): (1) dialogue (socialization is transferred to externalization); (2) linking explicit knowledge (externalization is transferred to combination); (3) learning by doing (combination is transferred to internalization); and (4) field building (internalization is transferred to socialization) (Nonaka and Takeuchi, 1995; Nonaka and Konno, 1998; Martin-De-Castro, Lopez-Saez and Navas-Lopez, 2008; Vaccaro, Veloso and Brusoni, 2009). The process encompasses five phases: (1) sharing tacit knowledge; (2) creating the concept; (3) justifying the concept; (4) building an archetype; and then (5) obtaining cross-leveling knowledge over time (Nonaka and Takeuchi, 1995; Nonaka and Konno, 1998). In short, there are three dimensions, tacit knowledge-explicit knowledge, time, and environment or "Ba". To summarize, there are two spirals; one knowledge spiral comprised of explicit and tacit knowledge that rise upward; the second spiral is comprised of intraorganization and interorganization factors that are activated along a time dimension. These two spirals interact to produce innovation (Nonaka and Takeuchi, 1995).

3.2 Restating and Modifying Nonaka's Knowledge-Creation Spiral Process

Nonaka and his colleagues (1995; 1998) developed the theory of organizational knowledge creation to explain the process of knowledge creation. The organization mobilizes tacit knowledge created and accumulated by individuals to organizationally amplify and crystallize knowledge to a higher organization level via SECI modes of explicit and tacit knowledge conversion. Dialogue, linking to explicit knowledge, learning by doing and field building are triggers of knowledge conversion (Nonaka and Konno, 1998). The innovation emerges out of the interaction of these spirals (Nonaka and Takeuchi, 1995).

The description of the second spiral above indicates the dynamic movement of knowledge including the forward effect (i.e., knowledge moving from left to right) and the feedback effect (i.e., knowledge moving back again to the left). Since they focus on organization-level studies, the net (forward and feedback) effect confines the further expansion of the theory applied to: (1) micro and macro "diffusion" of Innovations (e.g., Rogers, 2003), (2) "Patterns of Industrial Innovation" (e.g., Abernathy and Utterback, 1978) including product and process (3) innovation evolution in the environment, and (4) integration of knowledge. This study takes into account both forward and feedback effects on knowledge creation-selection-diffusion spiral along the ontological dimension. The forward effect ascribes feedback effect to knowledge assets (Leonard-Barton, 1995; Schilling and Kluge, 2009) and expands the work of Nonaka and Takechi (1995).

Another necessary modification is replacing tacit knowledge-explicit knowledge with innovation-efficiency in the epistemological dimension. Despite tacit knowledge and explicit knowledge being critical constructs depicting the SECI modes of knowledge conversion which creates knowledge in the work of Nonaka and Takeuchi (1995), the classification of knowledge was criticized by Gourlay (2006). He criticized the four SECI modes commenting that three of the four modes appear plausible; however, none are supported by evidence that cannot be explained more simply by replacing tacit knowledge and explicit knowledge with non-reflective behavior and reflective behavior. Others have argued that innovation and efficiency, rather than tacit and explicit knowledge, are constructs used more frequently in organizational studies (Graetz and Smith, 2008) and strategy management (e.g., Miles and Snow, 1978; Tangpong, Michalisin and Melcher, 2008). The resulting view, therefore, is an unerring relationship between tacit knowledge and innovation. Once the importance of tacit knowledge is realized, then it becomes possible to adopt an entirely new perspective on innovation (Mascitelli, 2000).

By restating and modifying the work of Nonaka and Takeuchi (1995), this study proposes a three-dimensional innovation process spiral for integrating innovation creation, selection and diffusion studies. The three dimensions are: (1) innovation-efficiency in the epistemological dimension; (2) uncertain-certain environment (i.e., “Ba”) for learning and (3) the individual-organization-industry level, which is unidirectional from the micro to the macro level, along a time dimension (or ontological) dimension. Figure 1 shows the three-dimensional innovation creation-selection-diffusion spiral process.

4. Perspective of Innovation

4.1 Perspective of Innovation-Efficiency and Uncertain-Certain Environment Dimensions

Mechanisms shown in studies by Nonaka and Takeuchi (1995) and Leonard-Barton (1995) are embedded in the proposed three-dimensional model (Figure 1), and form the basis of the innovation creation-selection-diffusion spiral curve from the innovation-efficiency and uncertain-certain environment dimensions in Figure 2. Nonaka and Takeuchi (1995) posit that at the individual level organizations must build a specific environment of interaction for socialization where experiences and mental models through the use of metaphors or analogies that reveal tacit knowledge and engage in collective reflection. The dialogue in the specific environment triggers externalization where tacit knowledge is converted to explicit knowledge. The explicit knowledge comes from the individuals’ mental maps and links implicit and explicit knowledge to trigger knowledge by networking newly created knowledge and existing knowledge from other sections of the organization, thereby creating a new product, service, or managerial system. The importing of newly created knowledge from other sections makes the expanded environment uncertain. In this new uncertain environment members learn by doing which triggers

Figure 1
The Three-Dimensional Innovation Spiral Process

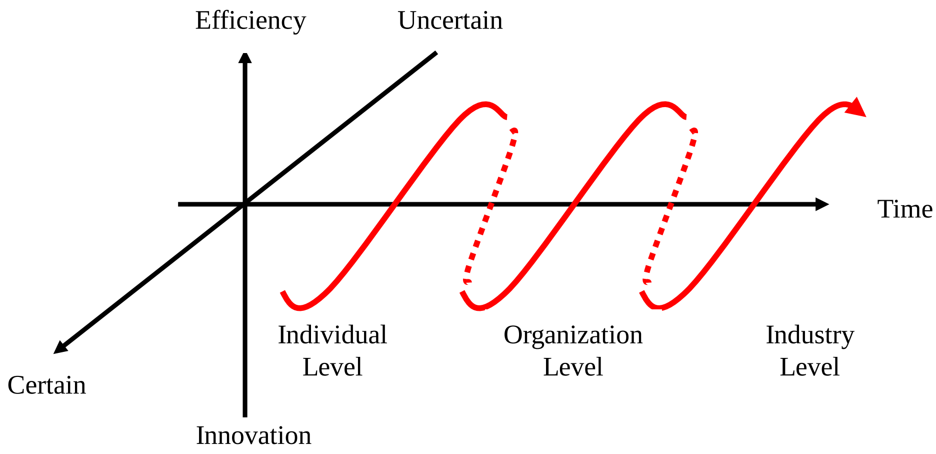
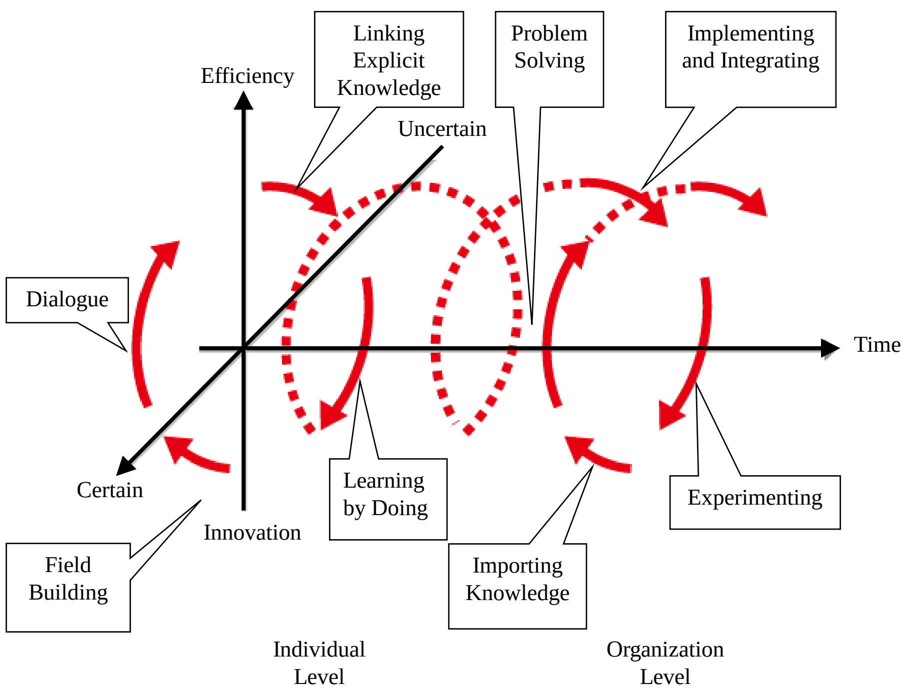


Figure 2
Mechanisms Facilitating Knowledge-Creation and Diffusion across Levels in the Three-Dimension Spiral Model



internalization (Nonaka and Takeuchi, 1995). Newness, diversity and confidence of individual learning lead to more innovation (Chang *et al*., 2013). The knowledge-creation spiral continues and eventually reaches a higher level. The projection of the innovation creation-selection-diffusion spiral process on the innovation-efficiency and uncertain-certain environment dimensions comprises the knowledge-creation mechanism of Nonaka and Takeuchi (1995).

From the perspective of Leonard-Barton (1995) regarding the organizational level, a knowledge-creation and diffusion begins when members in related functions with the same knowledge profiles are repetitively used by applying their existing knowledge to solve problems. Then, through constantly improving the production process there are continuous improvements in efficiency by decentralizing decisions about production methodologies by implementing and integrating activities. Creating knowledge requires the involvement of employees at all levels to drive innovation. Finally aggressively pursuing the latest industry knowledge by scanning external sources of expertise is essential. Pulling in expertise from outside completes the innovation to enhance the capabilities of problem solving in the field (Chou *et al*., 2014). These four sets of activities feed into and are derived from the organization's core capabilities (Leonard-Barton, 1995). Figure 2 shows knowledge creating and diffusing activities (Nonaka and Takeuchi, 1995; Leonard-Barton, 1995).

4.2 Perspective of Uncertain-Certain Environment and Time Dimensions

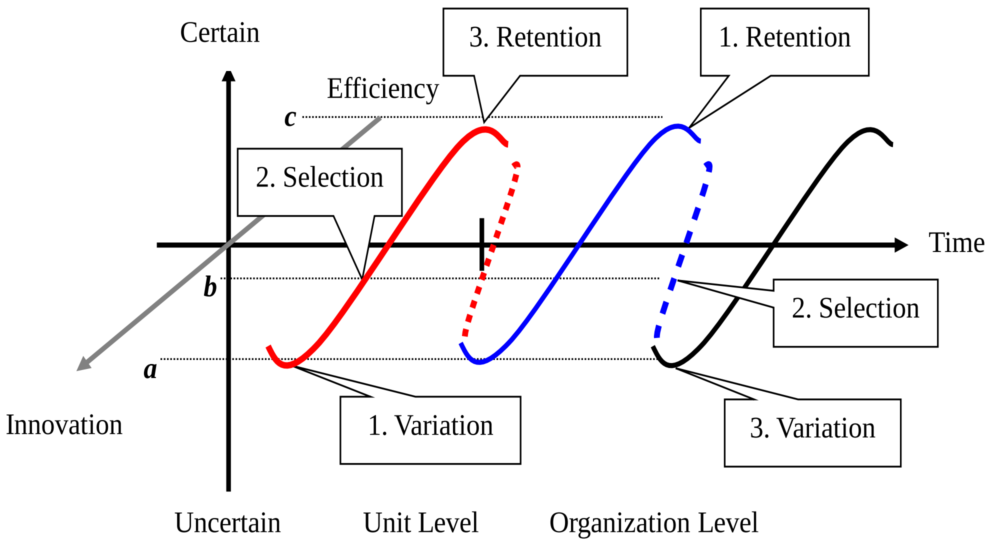
In the organizational ecology literature, organizations adapt to environmental changes to survive. Three isomorphic processes (coercive, mimetic, and normative) in the environment create similarity among organizations (DiMaggio and Powell, 1983; Boiral, 2003; Heugens and Lander, 2009). The sheer number of organizations adopting an innovation can cause a bandwagon pressure, prompting other organizations to adopt similar innovations (Abrahamson and Rosenkopf, 1993; Swanson and Ramiller, 2004; Nicolai, Schulz and Thomas, 2010). Organizational structure transforms to adapt at the institution-level (e.g., political system, laws, regulations, financial markets, and underlying assumptions about the purpose of economic activity) change (Newman, 2000). Structure results from conformity with the prevailing institutional logic in the environment (Thornton, 2002; Etzion and Ferraro, 2010).

For strategy, organizations choose between K-strategy and R-strategy. *K* symbolizes environmental carrying capacity, that is the species (i.e., industries) number N^* at which the time-rate of change $\Delta N/\Delta t = 0$. The symbol *R* signifies the maximum rate of Malthusian growth, obtainable without a constraining environment; *R*-strategists, are first to enter a new product or market domain (Boeker, 1991). Thus, *R*-strategies imply innovations. Organization life and death is determined by Darwinian selection and replacement while Lamarckian adapt to processes in the environment. Darwin, selection and replacement at the unit level may lead to Lamarckian adaptations at the organization level through purposive replication of successful forms (Usher and Evans, 1996; Marmefelt, 2009). Organizations in the selection/replacement environment are defenders and pursue cost leader strategies. Conversely, organizations with high (degree of) strategic choice are prospectors and pursue differentiation. These organizations are characterized by high innovation and autonomy; organizations in a selection and replacement environment are characterized by low innovation and autonomy (Hrebiniak and Joyce, 1985; Bantel, 1998).

Borrowing from organizational ecology theory, Burgelman (1991) and Burgelman and Grove (2007) use the selection mechanisms to develop two strategies: autonomous strategic process (i.e., V-S-R) and induced strategic process (i.e., R-S-V). From this knowledge ecology perspective, the role of innovation is a high strategic choice for the organizations to adapt to the environment; low degree of innovation high efficiency and high determinism (Hrebiniak and Joyce, 1985; Bantel, 1998). Autonomous and induced strategic processes reflect the frequency and magnitude of environmental changes for the organizations to adapt to the environment (Wholey and Brittain, 1986; Burgelman, 1991; Burgelman and Grove, 2007).

The points made by organizational ecologists form an essential part of the proposed three-dimensional model (Figure 1), when we view the innovation creation-selection-diffusion spiral curve from uncertain-certain and time dimensions. Figure 3 shows the Darwin process (V-S-R, shown as a bold grey line) in the unit level and Lamarckian process (R-S-V, shown as a dotted black line) at the organization level. At the industrial level, the organization can only pursue a R-strategy in an entrepreneurial manner or a K-strategy suitable for a relatively saturated environment as a high volume producer (Abernathy and Utterback, 1978). Initially the organization pursues the V-S-R track and over time morphs to the R-S-V track in response to the environment. Points *a*, *b*, and c, are the process projections on the innovation-efficiency and uncertain-certain environment dimensions. These points indicate that the environment changes from uncertain to certain (*a* → *b* → *c*, Darwin process) or from uncertain to certain (*c* → *b* → *a*, Lamarckian process). Environmental determinism and strategic choice represent organizational adaptation to nature (Hrebiniak and Joyce, 1985; Bantel, 1998).

Figure 3
The "Autonomous Strategic Process" or Darwin Process (V-S-R) and the "Induced Strategic Process" or Lamarckian Process (R-S-V) in the Three-Dimensional Spiral Model

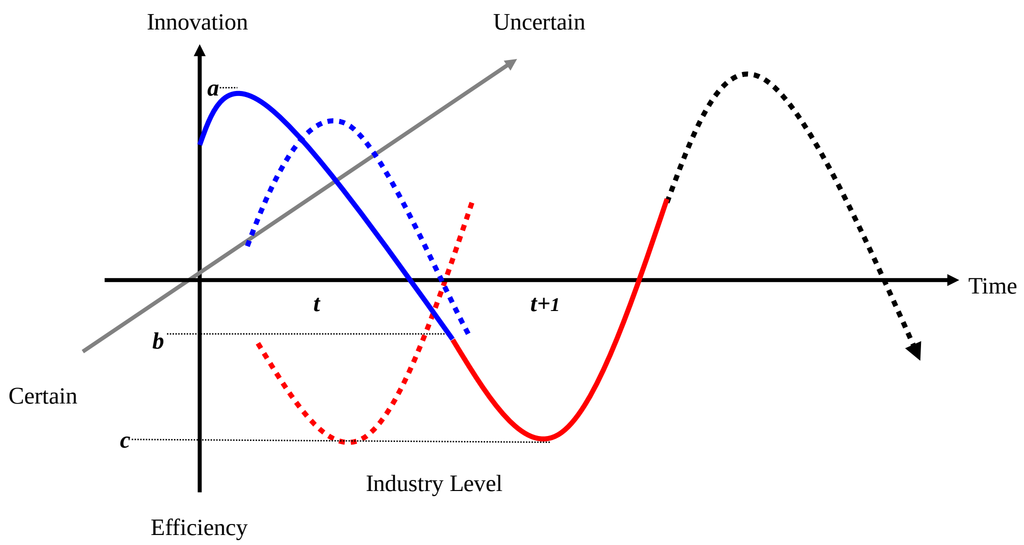


4.3 Perspective of Innovation-Efficiency and Time Dimensions

Abernathy and Utterback (1978) summarized their work and presented a model of related patterns of innovation which indicate that what constitutes a product innovation by a small, technology-based unit is often the process equipment adopted by a large unit to improve its high volume production (i.e., efficiency) of a standard product. Studies by Abernathy and Utterback (1978), Pavitt (1984), Tidd and Pavitt (2001), and Heidenreich (2009) indicate that a small unit initiates the product innovation, while a large unit carries on the task of the small unit to improve process innovation. Therefore, product innovation rate decreases after the initiation; process innovation rate increases to intersect with the decreasing product innovation curve.

The innovation creation-selection-diffusion spiral curve from innovation-efficiency and time dimensions (see Figure 1) is illustrated in Figure 4. The upwards innovation (changing knowledge profile) and downwards efficiency (continually utilizing and learning in the same knowledge profile) in the

Figure 4
The "Patterns of Industrial Innovation" in the Three-Dimensional Spiral Model



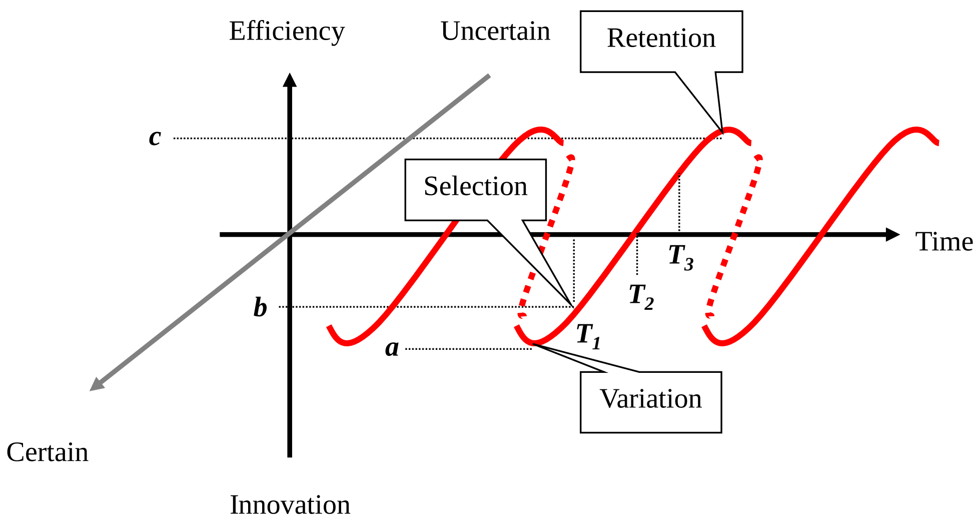
epistemological dimension present the idea's relative magnitude of newness. The small unit initiates product innovation at period "*t*" as shown by the bold black line. The large unit carries on the task of the small unit to improve process innovation (efficiency) during period *t+1* as shown by the grey bold line. Period "*t*" shows the rapidly changing and competitive environment that product innovation (generation *t*) uses process (generation *t-1*). CPU product innovation during period *t* using DRAM process technology of period *t-1* and is later transferred to other products. The process (generation *t-1*) used to improve high volume production is shown as a grey dotted line. When rate of innovation (and efficiency) is measured together with innovation magnitude, the grey dotted line is turned downside up along the time axis. Finally, the product innovation (black bold line) and process innovation (black dotted line) curves in the Figure 4 show product innovation and process innovation during period *t*.

The above explanation expands the work of Abernathy and Utterback (1978) from product innovation and process innovation in the same industry to product innovation in one industry using process innovation in another industry. The reason that product innovation and process evolving trajectories are separate, Christensen (1995) argued, is that there are four generic categories of assets: scientific research assets, process innovative assets, product innovative application assets and aesthetic assets. The asset categories differ profoundly with respect to their "functional" contribution to industrial innovation. Coupling between assets for industrial innovation is based on asset specificity (i.e., the degree which innovative activities based on one asset category implies idiosyncratic activities based on other asset category). The technological trajectories are determined by asset profile oscillations and regroupings. Consequently, product and process innovation can be seen as evolving separately where one product innovation leads to another initiating process innovation and upgrading (Nonaka and Takeuchi, 1995). In short, product innovation and process innovation evolve separately and enable each other. Rogers (2003) indicated that the (cumulative) adoption data can be represented via an S-shaped curve. The S-shaped curve is normal, and can be attributed to knowledge being communicated to reduce uncertainty in the diffusion process (Rogers, 2003;

Kuandykov and Sokolov, 2010).

The S-shaped curve is part of the proposed three-dimensional model (Figure 1), when the innovation creation-selection-diffusion spiral curve is viewed from innovation-efficiency and time dimensions, shown in Figure 5. Innovation in the organization theory or strategic management field is a synonym of variation in the ecology field and creates environmental uncertainty. Once a critical number of individuals adopt an interactive innovation, further diffusion becomes self-sustaining. The critical mass (T_1 in Figure 5) thus becomes a kind of tipping point or social threshold in the diffusion process (Rogers, 2003; Watts and Dodds, 2007; Delre *et al*., 2010). Therefore, if innovation diffusion can achieve critical mass, the innovation (variation), which is self-sustaining, can be selected out. The above era of intense technical variation and selection (era of ferment) culminate in a single dominant design (T_2, the variation adopted by early majority or T_3, the variation adopted by the late majority, whose behavior of adoption is cost driven in Figure 5). The era of incremental change, process innovation, begins (Anderson

Figure 5
The "Diffusion of Innovations"
in the Three-Dimensional Spiral Model



and efficiency is pursued. During the above process, uncertainty is reduced by information (knowledge) is created and shared by participants in the diffusion process. Without a second variation, the environment becomes certain again. Therefore, the critical mass, information communication (Rogers, 2003), dominant design, era of ferment, era of incremental change (Anderson and Tushman, 1990) and the variation-selection-retention framework of cultural evolution theory (Pohlmann, 2005) is depicted by the S-curve. Restated, the innovation creation-selection-diffusion spiral curve projects the innovation-efficiency and time dimensions and results in S-shaped curve. Points *a*, b, and *c*, which express the process projection of the innovation-efficiency and uncertain-certain dimensions, indicate that the environment changes from uncertain (innovation initiated) to certain (innovation diffused or efficiency pursued) owing to information (knowledge) creation and sharing (Rogers, 2003).

4.4 Toward a Dynamically Integrative Framework

The following relationships can be identified from the studies represented by the holistic and integrative three-dimensional spiral framework. Field building, dialogue, and linking explicit knowledge and learning by doing activities (Nonaka and Takeuchi, 1995) and problem solving, implementing and integrating, experimenting and importing activities (Leonard-Barton, 1995) are knowledge-creation and diffusion mechanisms, as the organization interacts with the environment, and are presented in the projection of the knowledge-creation and diffusion spiral process in the three-dimensional model on the innovation-efficiency and uncertain-certain environment dimensions.

Through tacit and explicit knowledge conversion of SECI modes via the above mechanisms in the organization, individual knowledge can be upgraded to an organizational knowledge level, and organizational knowledge can facilitate individual knowledge (Nonaka and Takeuchi, 1995). This bilateral interaction between individual and organizational knowledge is explained by the interaction between four activities and core capabilities (i.e., knowledge assets) (Leonard-Barton, 1995). Knowledge-creation and diffusion mechanisms facilitate a forward effect (from the micro individual level to macro organizational level) as well as the feedback effect (from the macro organizational level to micro individual level) by accumulating knowledge assets (core capabilities and resources).

Burgelman and Grove (2007) borrow the selection mechanism from the evolutionary school and use it to present the autonomous strategic process (V-S-R) and induced strategic process (R-S-V) as the strategy choices when the organization faces a rapidly changing environment. These two strategic processes are shown on the projection of knowledge-creation and diffusion spiral process in the three-dimensional model on the uncertain-certain environment and time dimensions. Organizational ecology or evolution (DiMaggio and Powell, 1983; Boiral, 2003; Heugens and Lander, 2009), the structure of the organization (e.g., Thornton, 2002; Etzion and Ferraro, 2010), the strategy of the organization (e.g., Boeker, 1991) and the life and death (or performance) of the organization (e.g., Usher and Evans, 1996; Marmefelt, 2009), emphasize the ultimate power of the environment, which influences the projection of the knowledge-creation and diffusion spiral process in the three-dimensional model on the uncertain-certain environment and time dimensions.

The product innovation and process innovation curves in the "Patterns of Industrial Innovation" (Abernathy and Utterback, 1978; Pavitt, 1984; Tidd and Pavitt, 2001; Heidenreich, 2009) are shown on the projection of the knowledge-creation and diffusion spiral process in the three-dimensional model of the innovation-efficiency and time dimensions. The S-curve representing the "Diffusion of Innovations" (Rogers, 2003; Kuandykov and Sokolov, 2010; Delre *et al*., 2010) is shown on the projection of the knowledge-creation and diffusion spiral process in the three-dimensional model of the innovation-efficiency and time dimensions.

Knowledge-creation and diffusion mechanisms at the organizational level provide a way for organizations to interact with the environment. From a knowledge perspective, this study argues that innovation and efficiency are comparable to environments such as information and communication technology industries. A performance to cost ratio represents customers' requirements of innovation and efficiency. When the market requires a high functional performance product, managers pursue a high innovation investment; conversely, when the market requires a high cost reduction product managers pursue high efficiency (Marion and Meyer, 2011). Optimal innovation-efficiency investment is influenced by the performance/cost ratio required by the industry.

Managers validate innovation related to product development in the environment over time by screening the S-curve pattern (e.g., slope change over time) in the industry. That is, the more rapid the conversion rate of the mechanisms accelerating innovation-creation and diffusion in the organization and enhancing the possibility of success, the steeper the slope of the S-curve (innovation diffusion in the industry). Organizations that adapt quickly to an environmental change via innovation have a high probability of success. High performance (resulting from product innovation) and low cost (resulting from process innovation) rapid conversion and the steeper slope of the S-curve (innovation-diffusing in short time) are the most critical success factors in the rapidly changing environment. That is, a viable innovation-creation and diffusion mechanism (organizational level) and screening S-curve pattern (industry level) are critical complementary activities in the innovation creation-selection-diffusion spiral process.

4.5 Resolving the Paradox of Supply-Side and Demand-Side Strategies in Industrial Innovation

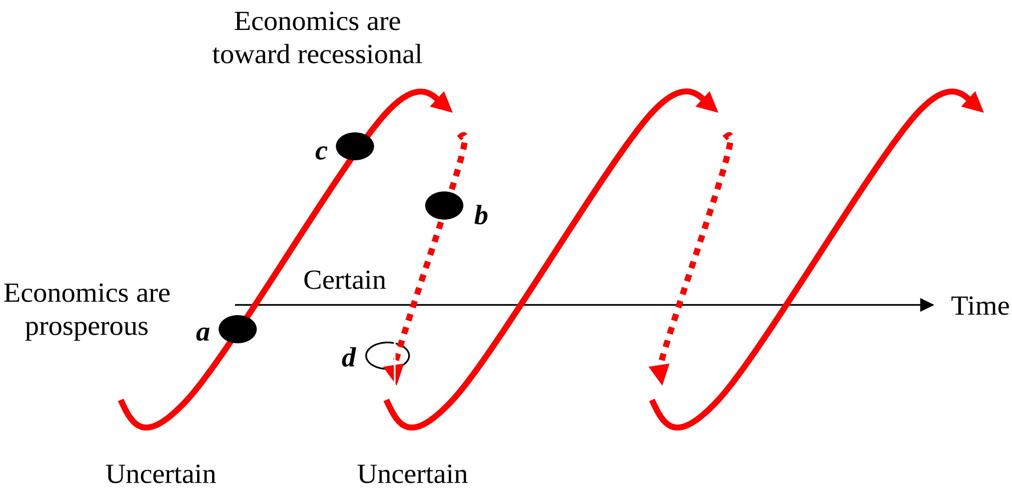
This three-dimensional spiral framework promotes a functional product performance/cost ratio for competitive strategies under the assumption that magnitudes of innovation and efficiency are comparable as shown in Figure 4 when firms seek strategies to adapt to environmental change. The work of Hung (2010) indicates that this results in five strategies: The first strategy is seeking innovation for high performance. The second strategy is seeking efficiency for low cost. The third strategy is seeking a lower cost corresponding to customers' willingness to pay (Adner and Levinthal, 2001) for a higher performance/cost ratio. The fourth strategy is increasing performance at a relative stable cost (Adner and Levinthal, 2001) for a higher performance/cost ratio and relative innovation. The fifth strategy is increasing performance while reducing cost.

These strategies help firms adapt to economic cycles as shown in Figure 6. Firms adopting strategy seeking innovation for high performance "before" point *a* and strategy seeking efficiency for low cost "after" point *a* demonstrates the viewpoints of Abernathy and Utteback (1978) that firms adapt to a technological environment change from uncertain to certain by innovation and efficiency. Conversely, firms adopting strategy seeking innovation for high performance "before" point *a* or strategy seeking a lower cost corresponds to customers' willingness to pay in stage *c*-*b* and strategy increasing performance at a relative stable cost "after" point *d*. These strategic choices demonstrate the viewpoints of Adner and Levinthal (2001) that firms adapt to environment changes by employing two strategies: innovation and relative efficiency. More definitively, existing strategies are confronted with the challenging conditions of the global landscape a "radical innovation" strategy that ensues as a coping mechanism to change. The new innovation is learned and a "relative efficiency" strategy follows which in turn, is followed by a "relative innovation" strategy. This strategy adaptation process allows the firm to pursue relative cost reduction coupled with relative performance enhancement. The strategic balance of innovation and relative efficiency resolves the paradox of supply-side and demand-side strategies in industrial innovation.

5. Discussions

Grounded on the work of Nonaka and Takeuchi (1995), studies on knowledge management provide innovation with an integrative direction. The mechanism for converting tacit and explicit knowledge in the epistemology dimension provides theoretical grounds for a source of innovation (i.e., knowledge creation) from individuals to organizations in the ontology dimension. Creative firms react to environmental perturbations by self-organizing: finding new ideas, new solutions, new products, and new markets. Perturbations produce creativity that is a fundamental mechanism for the firm to evolve and adapt in the environment (Kelley, 2009). Creativity facilitates innovation and innovation is crucial for creating value in the marketplace (Hill and Birkinshaw, 2010). "To be

Figure 6
Corresponding Relationship between Economics Cycle and Environment Cycle



creative, you need to know something…What you need to know depends on just how you're being creative…To succeed in most endeavors, you have to have knowledge that is necessary for adapting to the environments (Sternberg and Lubart, 1995)." The new creative idea becomes innovation and diffuses in the industry or the society after selection of the market environment (Burgelman and Grove, 2007; Hung, 2010). This study expands the work of Nonaka and Takeuchi (1995) to a three-dimensional integrative framework and contributes from both theoretically and applied perspectives as discussed below.

5.1 Theoretical Implications

5.1.1 Resolving the Paradoxical Strategies of Innovation

This study contributes by offering up a new (three-dimensional) perspective on prior innovation studies. Current approaches to the study of innovation suggest a paradox. Abernathy and Utterback (1978) pursue functional product performance (absolute innovation strategy) in the beginning of industrial innovation and cost (absolute efficiency strategy) in the late stages. Alternatively, Adner and Levinthal (2001) suggest reducing prices (cost) to a level that consumers are willing to pay (relative efficiency strategy) in the early stages, and increasing performance at a relatively stable product price (relative innovation strategy) in the later stages. Absolute innovation, absolute efficiency, relative efficiency and relative innovation strategies align on the innovation trajectory. They are not paradoxical in the three-dimensional framework. This study explains that restricted two-dimensional observation (on innovation-efficiency and time dimensions) results in the paradox of supply-side and demand-side strategies in industrial innovation.

5.1.2 Knowledge Creation, Selection and Diffusion Mechanisms in the Innovation Process Form a Three-Dimensional Framework Perspective

Knowledge-creation and diffusion mechanisms such as field building, dialogue, linking explicit knowledge and learning by doing (Nonaka and Takeuchi, 1995) or problem solving, implementing and integrating, experimenting and importing knowledge (Leonard-Barton, 1995) should be the focus of organizations in relation to their environment. Organizations should interact synchronously by innovating in an uncertain environment and pursuing efficiency in a certain environment at the organization level of the ontology dimension.

Over-time, uncertain-certain environment change regulates or limits the innovation process. The selection mechanism provides the autonomous strategic process (V-S-R) and induced strategic process (R-S-V) in the strategy management field or the corresponding Darwinian process and Lamarckian process in the organizational ecology field at the industry level of the ontology dimension. Innovation-efficiency transition over time in the epistemology dimension drives the product innovation and process innovation curves in Pattern of Industrial Innovation and the S-curve in “Diffusion of Innovations” (from individual or organization level to industry level) in the ontology dimension.

5.2 Managerial Implications

This study indicates that product innovation and process innovation evolve separately and enable each other in the innovation process according to the direction of the high performance/cost ratio. This indication elucidates and ushers in the possible success of new value chain disintegration. Taiwan Semiconductor Manufacturing Corporate (TSMC), a pure foundry company in the global semiconductor industry focuses on process innovation and manufactures integrated circuit (IC) products of fabless design-houses. Professional division of labor between foundries and design-houses accelerate product and process innovations which quickly respond to heterogeneous demands and provide customers high performance/cost ratio products (Hung, 2010; Santos and Spann, 2012). Vertical disintegration creates entrepreneurial opportunities for managers. In order to make a successful innovation-efficiency transition over time, organizations must adapt to the environmental change of their industry. This study points out three critical competitive advantages in the innovation process (Tatikonda and Rosenthal, 2000; Jacobs *et al*., 2011). Given a rapid mechanism transition and a steeper rate of developing the S-curve, the organization can rapidly achieve performance (resulting from innovation) and cost (resulting from efficiency) in a short development time. A well-designed structure (virtual team/collocated team) with a trusting work environment facilitates organizations to transition (Chou *et al.*, 2014). This model contributes by bridging the gap between strategic decision (innovation or efficiency) and environment (uncertain or certain) by selection mechanisms (V-S-R or R-S-V) and provides an integrative framework for innovation creation-selection-diffusion studies.

5.3 Research Limitations and Future Studies

The integrative framework for innovation is based on key studies on industrial innovation, innovation diffusion, organizational ecology, strategic management, and knowledge management, related to the three-dimensional innovation spiral process. To advance the model further more theoretical and practical development should be undertaken through more detailed and relevant studies should be verified in the integrative framework. Future innovation studies may use the three-dimensional framework to resolve two-dimensional paradoxes such as innovation-efficiency paradoxes in the uncertain-certain environment on cross-sectional (e.g., innovation-efficiency and uncertain-certain environment dimensions) or longitudinal (e.g., innovation-efficiency and time dimensions) from a three-dimensional perspective.

6. Conclusions

Based on research of knowledge management, organizational ecology, strategy management, industrial innovation, and innovation diffusion, this study re-conceptualizes the work of Nonaka and Takeuchi (1995) to propose a three-dimensional (innovation-efficiency, certain-uncertain environment, and time) spiral model. The work of Nonaka and Takeuchi (1995) or Leonard-Barton (1995) is reflected in the projections of the three-dimensional spiral model on the innovation-efficiency and uncertain-certain environment dimensions; studies on areas such as organizational ecology and strategy management borrowing selection mechanism such as V-S-R or R-S-V strategy. Burgelman and Grove (2007) from evolutionary school are drawn upon in the projections of the three-dimensional spiral model on the uncertain-certain environment and time dimensions; moreover, the product innovation and process curves in the Pattern of Industrial Innovation (Abernathy and Utterback, 1978) and the S-curve depicting "Diffusion of Innovations" (Rogers, 2003) are presented in the projections of the three-dimensional spiral model on the innovation-efficiency and time dimensions.

In sum, the above areas of study can be restated in the three-dimensional spiral framework when the innovation creation-selection-diffusion process is viewed from different dimensions. The process projection on the innovation-efficiency dimension and uncertain-certain dimension depicts the knowledge-creation and diffusion mechanisms at the organizational level; the process projection on the uncertain-certain dimension and time depicts the selection mechanism of the environment deterministic evolution such as autonomous strategic process or induced strategic process at the industrial level; the process projection on the innovation-efficiency and time dimensions depicts the S-curve of "Diffusion of Innovations" and product innovation/process innovation curves from the individual or organization level to the industry level.

Reviewing the three-dimensional innovation-creation and diffusion spiral model, the holistic and integrative framework recommends: (1) to expand the work of Abernathy and Utterback (1978) to identify the product innovation curve and process innovation curve in vertical-integration industries and vertical-disintegration industries such as IC design houses and foundries by separating product innovation and process innovation curves' evolutions; (2) accelerating conversion rates of activities (mechanism) in the organization, as well as, screening the slope change of the innovation diffusion (S-curve) synchronously in the industry for effective innovation execution and validation; (3) firms' strategy choice (autonomous strategy or induced strategy) adapting to environment changes (technology environment changes from uncertain to certain or change from certain to uncertain) and seeking a high performance/cost ratio to create value for customers and society. Thus, this framework not only resolves the paradox of supply-side and demand-side strategies in industrial innovation it also suggests implications for theory development and practices.

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